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September 14, 2010

Mr. Scott T. Anderson, Director
Division of Solid & Hazardous Waste
P.O. Box 144880
Salt Lake City, UT 84114-4880

Attn: Pat Sheehan

Subject: Human Health and Ecological Risk Assessment, former Indian Oil Facility

Dear Mr. Anderson,

As requested by the Division of Solid & Hazardous Waste, AEEC, LLC (AEEC) is submitting a human health and ecological risk assessment ("risk assessment") for the former Indian Oil Facility (the "Site") located at 1155 West 135 South in Lindon, Utah (Section 32 of Township 5 South, Range 2 East, SLB&M). The Site was formerly operated to rerefine used oil into various petroleum products. The risk assessment evaluates the potential risks associated with conditions that exist or are anticipated to exist at the subject property, assuming that the Site will remain an industrial property after closure in accordance with Utah Hazardous Waste Rules R315-101-5.2(b)(2).

This submittal contains the following:

- One hard copy of the Human Health and Ecological Risk Assessment and accompanying appendices; Appendix A - Johnson and Ettinger Model Output, Appendix B - Letter from Utah Division of Wildlife Resources.

Upon approval of this risk assessment, site closure with appropriate management activities/institutional controls will be requested, per R315-101. Should you need any additional information or have any questions please contact me at your convenience.

Sincerely,

Bryan Wheeler

Bryan Wheeler, P.E.
Project Engineer
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DEPARTMENT OF
ENVIRONMENTAL QUALITY

Human Health and Ecological Risk Assessment

for

Indian Oil

Prepared for:

Utah Department of Environmental Quality:
Division of Solid and Hazardous Waste

Prepared by:

American Environmental and Engineering Consultants, LLC

3489 West 2100 South, Suite 150

Salt Lake City, UT 84119

September 2010

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EXECUTIVE SUMMARY

A human health and ecological risk assessment ("risk assessment") was performed at the former Indian Oil Facility located at 1155 West 135 South in Lindon, Utah (Section 32 of Township 5 South, Range 2 East, SLB&M). The risk assessment evaluates risks associated with conditions that exist or are anticipated to exist at the subject property in accordance with Utah Hazardous Waste Rules R315-101-S.2(b)(2).

The Indian Oil facility was formerly operated to re-refine used oil into various petroleum products. In course of operation, some petroleum was released to the soil and groundwater. Corrective action in the form of Subsurface Metabolism Enhancement (SME, pat. #6,464,005) was installed around the shop building by Ellis Environmental and activated on August 4, 2006. The last report on SME progress indicated that the SME system indicated 100% removal of toluene, 99% reduction in benzene and 97% reduction in TPH from the start up concentrations. The site is currently unused.

Per the approved work plan (AEEC, 2010); the following'contaminants of concern (COCs) are included in the risk assessment (based data collected as part of past site investigations and monitoring events); benzene, vinyl chloride, cis 1,2-dichloroethylene, ethyl benzene, and 1,1-dichloroethane.

For an exposure pathway to be considered complete a contaminant must be present in the source media and the contaminant transport mechanisms must be active in the absence of any existing or future control measures (i.e. receptors could be potentially in contact with the affected media). Presently, the only identified complete exposure pathways at the subject property are the following:

- Direct dermal contact with groundwater by adult workers conducting Invasive construction/excavation activities
- Incidental ingestion by adult workers conducting invasive construction/excavation activities
- Inhalation of volatilized COCs (vapor intrusion to indoor air) from contaminated groundwater sources by installation workers

COCs in soil have not been detected and therefore, any exposure route that includes soil as a source medium is considered to be incomplete. While inhalation of volatilized COCs from contaminated groundwater sources by Site visitors is a potentially complete exposure pathway, it is considered insignificant and will not be evaluated in the risk assessment.

The toxicity information utilized for all identified COCs was obtained from, in order of preference, the Integrated Risk Information System (IRIS), California Environmental Protection Agency (CalEPA), and Massachusetts Department of Environmental Protection (MassDEP).

In accordance with the Utah Administrative Code Rule R315-101, Cleanup Action and Risk-Based Closure Standards, the risk characterization identifies carcinogenic risk, for individual and multiple substances, the non-carcinogenic hazardous Index (HI), hazard quotients (HQs) (where applicable), and their respective uncertainties. Cancer risks have been estimated using standard risk assessment methodology and are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to the COCs per the applicable exposure scenarios. The term "incremental" indicates that the calculated cancer risk associated with site related exposure is in addition to the background risk of cancer experienced by all individuals in the course of daily life (Integral, 2009). Health risks from non-carcinogens are characterized as the increased likelihood that an individual will suffer adverse health effects as a result of chemical exposure. To evaluate non-cancer risks, the ratio of the EC (i.e., average daily intake) to the corresponding non-carcinogenic toxicity reference value (i.e., RfD or RfC) is calculated. If the calculated value of the HQ is less than or equal to 1, no adverse health effects are expected. If the calculated value of the HQ is greater than 1, then further risk evaluation is needed.

The level of risk present at the site is less than 1×10^{4} but equal to 1×10^{-6} for carcinogens across all complete pathways and applicable COCs. The HI for individual substances and the total HI across all complete pathways and applicable COCs is less than one.

The potential for adverse effects to receptor ecosystems and species was evaluated in the approved work plan (AEEC, 2010), and was determined to be negligible. Any exposure route that includes soil as a source medium is considered to be incomplete, as soil samples collected at the facility on February 23, 2010 did not identify the presence of COCs above the laboratory detection limit. Exposure through inhalation of volatilized COCs is also considered to be a negligible, because volatiles disperse rapidly in outdoor air and airborne dust from surface soil does not contain detectable levels of COCs. Additionally, no aquatic habitat or standing water exists at the Site or within close proximity. Therefore, the potential risk to ecological receptors at the site is negligible.

As an appropriate management activity and in accordance with criteria identified in R315-101-1(b)(4), it is recommended that the extraction and/or use of groundwater at the Site be prohibited except for characterization purposes. All characterization activities must be conducted per Title R315 of the Utah Administrative Code.

1.0 INTRODUCTION

1.1 *OVERVIEW*

This report presents the results of a human health and ecological risk assessment ("risk assessment") performed at the former Indian Oil Facility located at 1155 West 135 South in Lindon, Utah (Section 32 of Township 5 South, Range 2 East, SLB&M). The risk assessment was performed as outlined in the August 2010 human health and ecological risk assessment work plan (AEEC, 2010).

1.1.1 Problem Statement

The risk assessment evaluates risks associated with conditions that exist or are anticipated to exist at the subject property. The risk assessment addresses potential exposures and risks assuming that the Site will remain an industrial property after closure in accordance with Utah Hazardous Waste Rules R315-101-5.2(b)(2).

1.1.2 Risk Assessment Objectives

As an alternative to performing cleanup to established standards, a human health and ecological risk assessment may be conducted to analyze potential environmental and human health risks resulting from exposure to impacted soil and groundwater. The purpose of this risk assessment is to determine the potential impact of existing contamination on human health and the environment at the subject property identified in Section 1.1. The risk assessment provides an analysis of potential exposure pathways, quantifies non-carcinogenic and carcinogenic risk, and presents the underlying assumptions/conclusions.

1.2 *BACKGROUND*

The Indian Oil facility was formerly operated to re-refine used oil into various petroleum products. In course of operation, some petroleum was released to the soil and groundwater. The release was documented by site investigation reported by Ellis Environmental Services, Inc. in April 4, 2005 and by Wasatch Environmental in January 6, 2005. These investigations were used by the Division of Solid & Hazardous Waste to issue a Notification of Contaminated Property, dated May 5, 2005, requiring corrective action be taken to eliminate soil and groundwater contamination. Corrective action in the form of Subsurface Metabolism Enhancement (SME, pat. #6,464,005) around the shop building was installed by Ellis Environmental and activated on August 4, 2006. SME operated for three months, then the owner of Indian Oil bankrupted, so the system was deactivated. The last report on SME progress indicated that the SME system indicated 100% removal of toluene, 99% reduction in benzene and 97% reduction in TPH from the start up concentrations.

1.2.1 Site Description

The Indian Oil facility is located in Utah County in the City of Lindon. Soils at the site generally consist of clay (CL) and overlying fine silty sand (SM). The soil is not so tight as to preclude in-situ methods of bioremediation. The major soil association is Aquic Calciustolls-Typic Calciaquolls-Fluvaquentic Haplustolls. The soil type for this area is described as Payson silty clay loam, 0 to 1 percent slope (Pd). The organic concentration of the deeper soil is 0.4%. The soil is strongly alkaline and moderately to strongly saline. The soil is moderately well drained and slowly permeable. Porosity is assumed to be

38%. Additionally, groundwater is encountered at approximately three to five feet below ground surface (bgs), and the calculated groundwater gradient direction is west-northwest (Ellis Environmental, 2005). Hydraulic conductivity at the site is estimated between 10^{-3} centimeters per second (cm/s) and 10^{-6} cm/s; 2.8 feet per day (ft/day) and 0.0028 ft/day, respectively (Fetter, 1994).

1.2.2 Current and Past Uses of the Site

The site is currently unused. As previously stated, the Indian Oil facility was formerly operated to re-refine used oil into various petroleum products. According to the Lindon City Department of Community Development (Building and Planning Division), the subject property is zoned light industrial. Adjoining parcels to the east, west, and south are also zoned light industrial. The adjoining parcel to the north is zoned heavy industrial.

1.2.3 Future Land Uses

Future land use at the subject property is anticipated to remain consistent with its zoning of light industrial. There is no apparent residential housing or agricultural activity in the vicinity.

1.2.4 General Sampling Locations

The data evaluated in the risk assessment were collected at the monitoring locations presented in Figure 1. All monitoring data were collected prior to development of the risk assessment by previous consultants and contractors. Samples collected by Ellis Environmental were analyzed by American West Analytical Laboratories for chlorinated solvents and petroleum hydrocarbons using Method 8260C and 5030C. Monitoring data collected by the Division of Solid and Hazardous Waste (DSHW) were analyzed by the Utah Division of Laboratory Services.

1.3 *ORGANIZATION OF RISK ASSESSMENT*

The risk assessment will follow the *Risk Assessment Guidance (RAGs) for Superfund Volume I Human Health Evaluation Manual (Part A)* (USEPA, 1989). The risk assessment is organized into the following sections:

- Section 1.0 – Introduction
- Section 2.0 – Identification of Chemicals of Concern (COCs)
- Section 3.0 – Exposure Assessment
- Section 4.0 – Toxicity Assessment
- Section 5.0 – Risk Characterization
- Section 6.0 – Ecological Risk Assessment
- Section 7.0 – Summary
- Section 8.0 – References

These sections provide a detailed overview of the approaches used to address potential human health risks associated with COCs that are present at the Site.

2.0 IDENTIFICATION OF COCS

Analytical data collected as part of past site investigations and monitoring events are the source of the data evaluated in the risk assessment (Table 1). Per the approved work plan (AEEC, 2010); the following COCs are included in the risk assessment:

- Benzene,
- vinyl chloride,
- cis 1,2-dichloroethylene,
- ethyl benzene, and
- 1,1-dichloroethane

Comparison of COCs to background levels and/or risk-based levels is not applicable.

2.1.1 Detected Analytes

Detected analytes were evaluated in the assessment at their reported values. The analysis is conservative, in that J-qualified analytical results have been used in the risk assessment.

2.1.2 Split Samples

All split samples were treated independently and have been used in the quantitative exposure assessment.

3.0 EXPOSURE ASSESSMENT

The extent of exposure for a given receptor is a function of the concentration of the contaminant in the exposure medium and the frequency, intensity, and duration of contact with that medium. The exposure assessment will consist of three fundamental steps: (1) exposure setting characterization, (2) exposure pathway identification, and (3) exposure quantification. Each of these steps is summarized below in Sections 3.1 through 3.4.

3.1 CHARACTERIZATION OF EXPOSURE SETTING

The exposure scenarios considered in the risk assessment are dependent upon the applicable exposure pathways and receptor populations based on potential and actual land use conditions. As discussed previously, the exposure scenarios to be evaluated at the Site assume that the site will remain as an industrial facility at closure. Residential exposure to contaminated groundwater does not occur and is unlikely to occur in the future, as there are no existing residential areas or special subpopulations (such as infants or the elderly) present. Section 1.2 discusses general receptor locations, the Site physical setting, and anticipated future land use.

3.1.1 Conceptual Site Model

A Conceptual Site Model (CSM) was developed to facilitate evaluation of exposure scenarios by identifying the source of the release, impacted media, transport mechanisms, exposure pathways, and any potential receptors. The CSM also identifies the combination of factors that could result in complete exposure pathways and potential human and environmental receptors that could result in potential harmful exposure to contaminants at the site. For the purposes of evaluating whether or not an exposure pathway is complete, the CSM considers both short-term exposure and long-term effects of an expanding or migrating contaminant plume. The completed CSM for the subject property is presented as Figure 2.

For each exposure pathway, the CSM has two possible outcomes: 1) Incomplete Pathway - Exposure pathway does not apply under current site conditions. 2) Complete Pathway - Exposure pathway is present and may pose an exposure route to current or potential receptors at a point of exposure. A brief explanation is provided in Section 3.2 for exposure pathways identified as incomplete, which includes the rationale for eliminating the pathway from future consideration. The risk assessment evaluates complete exposure pathways and quantifies risks to receptor populations.

3.2 EXPOSURE PATHWAYS

Exposure pathways are the route by which contamination migrates from the source (or exposure media) to the receptor(s) by way of the transport mechanisms. The exposure pathway assessment is a function of the physical site conditions, including the transport mechanisms and contaminant concentration, and the proximity of potential receptors. Mechanisms for contaminant transport include releases to groundwater from impacted soil (historical), contaminant convection-dispersion in groundwater, and volatilization of the contaminants from the aqueous phase. Impacted soils have been excavated and are no longer a potential exposure media.

3.2.1 Source Media

Contaminant releases to impacted media are attributed to the historical storage and handling of used oil. The assumed source area is the center section of the above-ground storage tank (AST) containment area where the bottoms of the ASTs were reportedly placed in direct contact with soil. The impacted soil was removed in December 2009, as described in the work plan (AEEC, 2010). A discussion of each media is presented in the following sections.

3.2.1.1 *Soil*

Historical waste management procedures have resulted in impacts to the soil medium in the AST Containment area. During the Limited Subsurface Investigation (dated February 5, 2003), soil impacts were observed at or above the zone of saturation (including the capillary fringe) in MW-3 located beside an oil/water separator, in MW-2 located opposite a process building and secondary containment area used for processing oil, and in MW-6 located near a 4,000-gallon underground sump.

More recently (February 2010), soil from under the eastern half of the used oil AST area was extensively characterized (Ellis Environmental, 2010). The results of this characterization indicate that no contamination was detected above actionable concentrations.

3.2.1.2 *Groundwater*

Historical releases of used oil have impacted groundwater at the subject property. During the Limited Subsurface Investigation (dated February 5, 2003), the presence of benzene was confirmed in groundwater samples. Concentrations exceeding the maximum contaminant level (MCL) were measured in MW-6, and low levels of 1,1-dichloroethane and cis 1,2-dichloroethylene were measured in MW-6 and MW-7 at concentrations below their respective screening levels (Wasatch Environmental, 2003).

Results from the October 2009 and June 2010 sampling events indicate that corrective action in the form of SME (pat. #6,464,005) has largely mitigated impacted groundwater at the subject property with the notable exception of MW-9. Impacts from petroleum constituents and chlorinated hydrocarbons persist at concentrations at or near the MCL at MW-9. Additionally, benzene, vinyl chloride, and cis 1,2-dichloroethylene were detected in split-sample results provided by the DSHW. Ethyl benzene and 1,1-dichloroethane were also detected in groundwater samples from this location but the results were less than the reporting limit and were qualified as estimates. A historical summary of groundwater sample results is presented in Table 1. It is notable that this summary includes data from the split-sample results.

3.2.2 Complete Exposure Pathways

For an exposure pathway to be considered complete a contaminant must be present in the source media and the contaminant transport mechanisms must be active in the absence of any existing or future control measures (i.e. receptors could be potentially in contact with the affected media).

Presently, the only identified complete exposure pathways at the subject property are the following:

- Direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities
- Incidental ingestion by adult workers conducting invasive construction/excavation activities
- Inhalation of volatilized COCs (vapor intrusion to indoor air) from contaminated groundwater sources by installation workers

As stated in Section 3.2.1.1 and the CSM, COCs in soil have not been detected and therefore, any exposure route that includes soil as a source medium is considered to be incomplete. While inhalation of volatilized COCs from contaminated groundwater sources by Site visitors is a potentially complete exposure pathway, it is considered insignificant and will not be evaluated in the risk assessment.

3.3 *GENERAL INTAKE ASSUMPTIONS*

Intake for incidental ingestion and dermal contact with groundwater was estimated for construction/excavation activity worker and installation worker receptor populations. The exposure assumptions applicable to the exposure estimates presented in Section 5.0 are presented below. EPA guidance was used as the basis for these assumptions, (refer to Section 3.3.2 for description).

3.3.1 Exposure Duration

The exposure duration (ED) is the length of time during which someone may be exposed to the contaminated medium via a specific exposure pathway. The ED varies depending upon the receptor population being evaluated. For a typical indoor occupational worker exposed to vapor phase COCs an ED of 30 years was used. This value is the default value for the Johnson and Ettinger (J&E) Model as implemented by EPA and represents a conservative upper bound estimate for the length of time a person works at the same location.

Construction workers are expected to work on limited term projects, such as building construction, and are assessed for sub-chronic exposures (i.e. <7 years). If multiple construction projects occur on the site, it is assumed that different workers will participate in each project. Therefore, an ED of 1 year for was used for adult workers conducting invasive construction/excavation activities at the Site, as recommended by EPA (USEPA, 2002).

3.3.2 Exposure Frequency

The exposure frequency (EF) describes how many days a receptor may have contact with contaminated media in a 1-year period. A default value of 350 days was used as the EF for a typical indoor occupational worker exposed to vapor phase COCs. The EPA recommended EF of 250 days per year was used for construction workers (USEPA, 2002).

3.3.3 Body Weight

A default value of 70 kilograms (kg) was used for all worker scenarios (both installation and construction workers).

3.3.4 Averaging Time

The averaging time (AT) is the period over which an exposure is averaged. The ATs for evaluating carcinogenic and non-carcinogenic effects are different, and are expressed in different units depending on the exposure pathway evaluated. For evaluating carcinogenic effects, chemical intakes were averaged over a 70 year lifetime (25,550 days). For evaluating non-carcinogenic effects, chemical intakes were averaged over the ED.

3.4 *QUANTIFICATION OF EXPOSURE*

Contaminant exposures for applicable scenarios were calculated using the detected concentrations described in Section 3.4.1 (assuming steady state conditions) and a receptor scenario based on current zoning and future land use planning considerations. Exposure dose equations that consider contact rate, receptor body-weight, and the frequency and duration exposure were used to estimate the dermal intake and incidental ingestion of each COC for each receptor. A J&E Model was used to estimate indoor exposure to installation workers from vapor intrusion. The equations and parameters used for each exposure pathway-specific calculation are presented in Section 5.0. The intake equations and exposure parameter values used in the risk assessment were based on EPA guidance documents, including *RAGS* (EPA, 1989) and *RAGS, Volume I: Human Health Evaluation Manual, "Part E, Supplemental Guidance for Dermal Risk Assessment."* (EPA, 2004). Both non-carcinogenic and carcinogenic risks were evaluated.

3.4.1 Exposure Point Concentrations

As there are insufficient data to determine the 95% upper confidence limit (UCL) on the arithmetic mean, exposure concentrations in groundwater was based on the maximum detected values measured during the June 1, 2010 sampling event (Table 1).

4.0 TOXICITY ASSESSMENT

The toxicity information utilized for all identified COCs was obtained from, in order of preference, the Integrated Risk Information System (IRIS), California Environmental Protection Agency (CalEPA), and Massachusetts Department of Environmental Protection (MassDEP). The following sections describe the source and date of the toxicological information used to evaluate non-carcinogenic and carcinogenic risks at the Site.

4.1 TOXICITY INFORMATION FOR CARCINOGENIC EFFECTS

The slope factors (SFs), Unit Risk Factors (URFs) and weight-of-evidence classification for benzene, vinyl chloride, and 1,1-dichloroethane are as follows:

Chemical	SF (Oral) (kg-day/mg)	URF $(\mu g/m^3)^{-1}$	Weight-Of-Evidence Classification	Source
benzene	5.50E-02	7.8E-06	A	IRIS Database, 2010
vinyl chloride	7.20E-01	8.8E-06	A	IRIS Database, 2010
1,1-dichloroethane	5.70E-03	1.6E-06	C	CalEPA, 1999

4.2 TOXICITY INFORMATION FOR NON-CARCINOGENIC EFFECTS

The chronic reference doses (RfDs) and inhalation Reference Concentrations (RfCs) for benzene, vinyl chloride, ethylbenzene, cis-1,2-dichloroethylene, and 1,1-dichloroethane are as follows:

Chemical	RfO (Oral) (mg/kg-d)	RfC (Inhalation) (mg/m^3)	Source
benzene	4.00E-03	3.0E-02	IRIS Database, 2010
vinyl chloride	3.00E-03	1.0E-01	IRIS Database, 2010
ethylbenzene	1.00E-01	1.0E+00	IRIS Database, 2010
cis-1,2-dichloroethylene	1.00E-02	3.5E-02	MassDEP, 2010
1,1-dichloroethane	3.50E-02	5.0E-01	MassDEP, 2010

4.3 COCS FOR WHICH NO EPA TOXICITY VALUES ARE AVAILABLE

Oral RfD values were not available for cis-1,2-dichloroethylene and 1,1-dichloroethane in EPA's IRIS database and there are limited data on the toxicity of cis-1,2-dichloroethylene and 1,1-dlchloroethane. However, oral RfDs were available in the 2010 Standards & Guidelines for Contaminants in Massachusetts Drinking Water (MassDEP, 2010).

SF and URF values were not available for 1,1-dlchloroethane in EPA's IRIS database but were available from CalEPA. The source document for the SF and URF values obtained from CalEPA was listed as *Air Toxics Hot Spots Program Risk Assessment Guidelines: Part II. Technical Support Document for Describing Available Cancer Potency Factors* (CalEPA, 1999).

5.0 RISK CHARACTERIZATION

In accordance with the Utah Administrative Code Rule R315-101, Cleanup Action and Risk-Based Closure Standards, the risk characterization identifies carcinogenic risk, for individual and multiple substances, the non-carcinogenic hazardous index (HI), hazard quotients (HQs) (where applicable), and their respective uncertainties (Section 5.2). The Site risk characterization is presented in the following sections.

5.1.1 Carcinogenic Risk of Individual Substances

Cancer risks have been estimated using standard risk assessment methodology and are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to the COCs per the applicable exposure scenarios. The term "incremental" indicates that the calculated cancer risk associated with site related exposure is in addition to the background risk of cancer experienced by all individuals in the course of daily life (Integral, 2009).

<u>Dermal Exposure to Groundwater</u>

SFs are not typically available for assessing the dermal exposure route. Oral SF values are typically used instead. Because oral SF values are usually derived from administered doses, while dermal exposure estimates are expressed as absorbed doses, the oral SF values must be adjusted to reflect the absorbed dose. This adjustment is accomplished by multiplying the oral SF by an absorption efficiency rate. The absorption efficiency rate is an expression of the fraction of contaminant absorbed in the gastrointestinal tract in the critical toxicity study. An assumed absorption efficiency of 20% has been used for all administered to absorbed dose conversions.

The absorbed dose of carcinogenic COCs from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities were calculated using Equation 1.1 as follows (Louvar, 1998):

$$D = \frac{C_{GW} \times A_S \times RD \times ET \times EF \times ED \times K_v}{W_B \times AT} \qquad \text{Eq. 1.1}$$

where,

> D = Dose of the chemical via the specified exposure route (mg/kg-day); lifetime average daily dose (LADD) for carcinogens, average daily dose (ADD) for non-carcinogens
> C_{GW} = Contaminant exposure point concentration (mg/L)
> A_s = Skin surface area available for contact (cm^2)
> RD = Dermal permeability constant (cm/hr)
> ET = Exposure time (hours/day)
> EF = Exposure frequency (days/year)
> ED = Exposure duration (years)
> K_v = Volumetric conversion factor (1/1000 L / cm^3)
> W_B = Body weight (kg)
> AT = Averaging time (days)

Input values and the calculated LADDs for carcinogenic COCs from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities are presented in Table 2.

Excess incremental lifetime cancer risks from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities were calculated using Equation 1.2 as follows (Louvar, 1998):

$$Cancer\ Risk\ (unitless) = LADD \times SF_{abs} \qquad \text{Eq. 1.2}$$

where,

LADD = Lifetime average daily dose of the chemical via the specified exposure route (mg/kg-day)
SF_{abs} = Cancer slope factor (kg-day/mg), adjusted to absorbed dose

The cancer risks from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities have been tabulated for COCs identified as human carcinogens (Section 4.1) in Table 2. It is notable that the SF has been converted from an administered to an absorbed dose using a 20% (assumed) absorption efficiency.

Incidental Ingestion of Groundwater

The intake of carcinogenic COCs from the incidental ingestion of groundwater by adult workers conducting invasive construction/excavation activities were calculated using Equation 2.1 as follows (Louvar, 1998):

$$D = \frac{C_{GW} \times RC \times ET \times EF \times ED}{W_B \times AT} \qquad \text{Eq. 2.1}$$

where,

D = Dose of the chemical via the specified exposure route (mg/kg-day); lifetime average daily dose (LADD) for carcinogens, average daily dose (ADD) for non-carcinogens
C_{GW} = Contaminant exposure point concentration (mg/L)
RC = Contact rate (l/hr)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
W_B = Body weight (kg)
AT = Averaging time (days)

Input values and the calculated LADDs for carcinogenic COCs from the incidental ingestion of groundwater by adult workers conducting invasive construction/excavation activities are presented in Table 3. Excess incremental lifetime cancer risks from the incidental ingestion of groundwater by adult workers conducting invasive construction/excavation activities were calculated using Equation 2.2 as follows (Louvar, 1998):

$$Cancer\ Risk\ (unitless) = LADD \times SF_{adm} \qquad \text{Eq. 2.2}$$

where,

LADD = Lifetime average daily dose of the chemical via the specified exposure route (mg/kg-day)
SF_{adm} = Cancer slope factor (kg-day/mg), administered dose

The cancer risks from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities have been tabulated for COCs identified as human carcinogens (Section 4.1) in Table 3.

Vapor Intrusion

Excess incremental lifetime cancer risks from the inhalation of volatilized COCs from contaminated groundwater sources by installation workers (vapor intrusion) were estimated by using the J&E model. The J&E model output is provided in Appendix A. The following input parameters were used:

Input Parameter[1]	Value	Basis
Benzene	13.5 µg/L	Maximum detected value measured during the June 1, 2010 sampling event
Vinyl Chloride	3.0 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
1,1-Dichloroethane	0.5 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
Averaging time for carcinogens	70 yrs	Default value
Exposure duration	30 yrs	Default value
Exposure frequency	350 days/yr	Default value
Average groundwater temperature	13 °C	Default value
Depth below grade to bottom of floor space	15 cm	Default value; assumes 6-inch thick slab on grade
Depth below grade to water table	122 cm	Average depth to water measurement at MW-9
SCS soil type directly above water table	CL	Geologic log of boring at MW-9
Vadose zone SCS soil type	CL	Geologic log of boring at MW-9

[1]Default input values were used for all parameters not listed.

The cancer risks from the inhalation of volatilized COCs from contaminated groundwater sources by installation workers (vapor intrusion) have been tabulated for COCs identified as human carcinogens (Section 4.1) in Table 4.

5.1.2 Carcinogenic Risk (Multiple Pathways)

Estimating the cumulative cancer risk requires the combination of simultaneous exposures to multiple COCs by more than one pathway, assuming dose additivity. The lifetime cancer risk for simultaneous exposures is calculated as follows (Louvar, 1998):

$$Risk_T = \sum_{i=1}^{n} Risk_i$$ Eq. 3.1

where,

$Risk_T$ = Total pathway cancer risk (unitless probability)
Risk = Risk estimate for the *i*th substance
n = Number of simultaneous exposures

The cancer risk for the applicable exposure pathways at the Site are calculated using Equation 3.2 as follows (Louvar, 1998):

$$Risk_T = Risk_{dermal\ exposure} + Risk_{incidental\ ingestion} + Risk_{vapor\ intrusion}$$ Eq. 3.2

where,

$Risk_T$ = Total exposure cancer risk (unitless probability)
$Risk_{dermal\ exposure}$ = Total dermal exposure cancer risk (unitless probability)
$Risk_{incidental\ ingestion}$ = Total incidental ingestion cancer risk (unitless probability)
$Risk_{vapor\ intrusion}$ = Total vapor intrusion cancer risk (unitless probability)

The total exposure cancer risk across all complete pathways and applicable COCs is presented in Table 5.

5.1.3 Hazard Quotient Calculation (Individual Substances)

Health risks from noncarcinogens are characterized as the increased likelihood that an individual will suffer adverse health effects as a result of chemical exposure. To evaluate noncancer risks, the ratio of the EC (i.e., average daily intake) to the corresponding non-carcinogenic toxicity reference value (i.e., RfD or RfC) is calculated. This ratio is referred to as the HQ. If the calculated value of the HQ is less than or equal to 1, no adverse health effects are expected. If the calculated value of the HQ is greater than 1, then further risk evaluation is needed.

Dermal Exposure to Groundwater

RfDs are not typically available for assessing the dermal exposure route. Oral toxicity values are typically used instead. Because oral toxicity values are usually derived from administered doses, while dermal exposure estimates are expressed as absorbed doses, the oral toxicity values must be adjusted to reflect absorbed dose. This adjustment is accomplished by multiplying the oral RfD by an absorption efficiency rate. The absorption efficiency rate is an expression of the fraction of contaminant absorbed in the gastrointestinal tract in the critical toxicity study. An assumed absorption efficiency of 20% has been used for all administered to absorbed dose conversions.

The dermal absorption of non-carcinogenic COCs from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities were calculated using Equation 1.1. Input values and the calculated LADDs for non-carcinogenic COCs from direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities are presented in Table 2.

Incidental Ingestion of Groundwater

The intake of non-carcinogenic COCs from the incidental ingestion of groundwater by adult workers conducting invasive construction/excavation activities were calculated using Equation 2.1. Input values and the calculated LADDs for non-carcinogenic COCs from the incidental ingestion of groundwater by adult workers conducting invasive construction/excavation activities are presented in Table 3.

Vapor Intrusion

The HQ from vapor intrusion to indoor air of non-carcinogenic volatilized COCs from contaminated groundwater sources by installation workers were estimated by using the J&E model. The J&E model output is provided in Appendix A. The following input parameters were used:

Input Parameter[1]	Value	Basis
Benzene	13.5 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
Vinyl Chloride	3.0 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
Ethylbenzene	0.8 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
Cis-1,2-Dichloroethylene	1.5 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
1,1-Dichloroethane	0.5 pg/L	Maximum detected value measured during the June 1, 2010 sampling event
Averaging time for noncarcinogens	30 yrs	Default value
Exposure duration	30 yrs	Default value
Exposure frequency	350 days/yr	Default value
Average groundwater temperature	13 °C	Default value
Depth below grade to bottom of floor space	15 cm	Default value; assumes 6-inch thick slab on grade
Depth below grade to water table	122 cm	Average depth to water measurement at MW-9
SCS soil type directly above water table	CL	Geologic log of boring at MW-9
Vadose zone SCS soil type	CL	Geologic log of boring at MW-9

[1]Default input values were used for all parameters not listed.

The HQ from vapor intrusion to indoor air of non-carclnogenic volatilized COCs from contaminated groundwater sources by installation workers have been tabulated for all COCs in Table 4.

5.1.4 Non-carcinogenic Hazard Index (Multiple Pathways)

The HI for non-carcinogenic effects requires the combination of simultaneous exposures to multiple COCs by more than one pathway, assuming dose additivity. The HI for simultaneous exposures is calculated as follows (Louvar, 1998):

$$HI = \sum_{i=1}^{n} HQ_i \qquad \text{Eq. 4.1}$$

where,

HI = Hazard index (unitless)
HQ_i = Hazard quotient for the *i*th substance (unitless)
n = Number of simultaneous exposures

The total hazard index (THI) for the applicable exposure pathways at the Site are calculated using Equation 4.2 as follows (Louvar, 1998):

$$THI = HI_{\text{dermal exposure}} + HI_{\text{incidental ingestion}} + HI_{\text{Vapor intrusion}} \qquad \text{Eq. 4.2}$$

where,

THI = Total hazard index (unitless)
$HI_{\text{dermal exposure}}$ = Total dermal exposure hazard index (unitless)
$HI_{\text{incidental ingestion}}$ = Total incidental ingestion hazard index (unitless)
$HI_{\text{vapor intrusion}}$ = Total vapor intrusion hazard index (unitless)

The cumulative THI across all complete pathways and applicable COCs is presented in Table 5.

5.1.5 Segregation of Hazard Indices

His for multiple chemicals are generally not summed if the reference doses for the chemicals are based on effects on different target organs. This is because the noncancer health risks associated with chemicals that affect different target organs are not likely to be additive. However, because the total HI does not exceed 1 for all COCs combined, a more refined analysis based on target organ was not conducted (Integral, 2009).

5.2 *UNCERTAINTY ANALYSIS*

Uncertainty is inherent throughout the risk assessment process, and is typically the result of a lack of knowledge of 1) site conditions, 2) toxicity data for COCs, 3) the extent to which a receptor population may be exposed to COCs, and/or 4) the representativeness of exposure point concentrations. Categories of uncertainties associated with the estimation of potential human health risks are discussed below.

Groundwater Sampling and Analysis Techniques

Groundwater sampling and analysis techniques, including sampling strategies, sample collection, and laboratory/instrument variability are sources of uncertainty. The uncertainties associated with sampling and analysis techniques are the result of systematic errors (or bias) and the degree of randomness or scatter in the data. These uncertainties cannot be estimated because the true value of each datum is unknown (Berthouex, 1994).

The Use of Maximum Concentrations

The use of maximum concentrations from select sampling locations as opposed to a statistical analysis of all groundwater data is a source of uncertainty and results in an overestimation of potential risks.

The J&E Model Assumptions/Limitations

Per the *User's Guide for the J&E (1991) Model for Subsurface Vapor Intrusion into Buildings* (EQM, 2000), the following represent the major assumptions/limitations of the J&E model.

- Contaminant vapors enter the structure primarily through cracks and openings in the walls and foundation.
- Convective transport occurs primarily within the building zone of influence and vapor velocities decrease rapidly with increasing distance from the structure.
- Diffusion dominates vapor transport between the source of contamination and the building zone of influence.
- All vapors originating from below the building will enter the building unless the floors and walls are perfect vapor barriers.
- All soil properties in any horizontal plane are homogeneous.
- The contaminant is homogeneously distributed within the zone of contamination.
- The areal extent of contamination is greater than that of the building floor in contact with the soil.
- Vapor transport occurs in the absence of convective water movement within the soil column (i.e., evaporation or infiltration), and in the absence of mechanical dispersion.
- The model does not account for transformation processes (e.g., biodegradation, hydrolysis, etc.).
- The soil layer in contact with the structure floor and walls is isotropic with respect to permeability.
- Both the building ventilation rate and the difference in dynamic pressure between the interior of the structure and the soil surface are constant values.

Many of the uncertainties associated with use of the J&E Model result from the uncertainty of input parameters. To balance these uncertainties, all model inputs are conservatively biased, particularly with respect to building height, air exchange rates, and exposure scenarios (ED, EF, etc.).

Site Hydrogeology

The complexity of Site hydrogeology is a source of uncertainty. The degree of uncertainty is similar to that of the sampling and analysis techniques, and is a function of the Site heterogeneity and systematic errors (or bias) and the degree of scatter in the data during site characterization. Many of the hydro-geologic properties of the Site (i.e., soil vapor permeability, capillary zone rise and diffusion, diffusive and convective transport, etc.) have never been measured directly and are assumed to be consistent with soil type.

Toxicity Values

Toxicity values are an additional source of uncertainty. Ethylbenzene, 1,1-dichloroethane, and cis-1,2-dichloroethylene toxicity values are based on the extrapolation of toxicity data from animal exposure studies and/or the extrapolation of a subchronic effect level to its chronic equivalent. An explanation of applicable uncertainty/variability factors (UFs) for each COC can be found in the IRIS database available at www.epa.gov/iris/subst/0308.htm.

The Use of Conservative Assumptions

The approaches, assumptions, and inputs used in the risk assessment have consistently been conservative, which gives confidence that the overall risk from exposure to COCs at the Site has been overestimated. The overestimated risk is more protective of human health at the Site and compensates for the lack of data that would be required for a more refined analysis.

6.0 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment provides a qualitative and quantitative analysis of the likelihood that adverse effects to receptors and/or ecosystems are associated with the environmental release of COCs. The following sections provide a qualitative analysis of potential exposure pathways and receptors present at the Site.

6.1 *ECOLOGICAL EXPOSURE ASSESSMENT*

Ecological exposure is defined as contact between an ecological receptor and one or more COCs present in an environmental medium. For exposure to occur, an exposure pathway must be complete as described in Section 3.2. Exposure is evaluated differently for receptors in continuous contact with an environmental medium (such as fish) versus those with intermittent exposure (i.e., birds and megafauna). For terrestrial ecological receptors, exposure to COCs may occur through four routes: 1) direct contact with soils, 2) inhalation, 3) incidental ingestion of soil as a result of feeding or grooming, and 4) ingestion of plants and animal prey. In aquatic habitats, exposure may also occur through three routes: 1) direct contact with contaminated water, 2) ingestion of water, and/or 3) ingestion of animal prey.

The potential for adverse effects to receptor ecosystems and species was evaluated in the approved work plan (AEEC, 2010), and was determined to be negligible. Any exposure route that includes soil as a source medium is considered to be incomplete, as soil samples collected at the facility on February 23, 2010 did not identify the presence of COCs above the laboratory detection limit. Exposure through inhalation of volatilized COCs is also considered to be a negligible, because volatiles disperse rapidly in outdoor air and airborne dust from surface soil does not contain detectable levels of COCs. Additionally, no aquatic habitat or standing water exists at the Site or within close proximity. Therefore, the potential risk to ecological receptors at the site is negligible.

6.1.1 Potential Receptors

Vegetation is restricted to the southern half of the western property boundary and along a 10 foot-wide strip bordering the southern and eastern fence-lines (AEEC, 2010). Vegetative species include Canada thistle, wheatgrass, cheatgrass, and other rangeland weeds. No terrestrial receptors, or evidence of receptors, are present at the site. The Utah Department of Natural Resources; Utah Division of Wildlife Resources (UDWR) provided information on species of special concern proximal to Indian Oil (Appendix B). UDWR does not have records of occurrence for any threatened, endangered, or sensitive species within the project area. There is currently no exposure route by which an aquatic receptor species could come into contact with a COC (see Section 6.1).

7.0 SUMMARY

The risk assessment identified potential receptors and exposure pathways to five COCs in groundwater at the Site. The only complete exposure pathways identified include direct dermal contact with groundwater by adult workers conducting invasive construction/excavation activities, incidental ingestion by adult workers conducting invasive construction/excavation activities, and inhalation of volatilized COCs (vapor intrusion to indoor air) from contaminated groundwater sources by installation workers. Detected analytes were evaluated in the assessment at their reported values. The analysis is conservative, in that J-qualified analytical results were used in the risk assessment.

The level of risk present at the site is less than 1×10^{4} but equal to 1×10^{6} for carcinogens and the THI is less than one for the Site. The risk assessment was conducted in accordance with R315-101-5.2(b)(2). The potential for adverse effects to receptor ecosystems and species was determined to be negligible.

7.1 CONCLUSIONS

A summary of the conclusions developed in the risk assessment are presented below:

- All conclusions stated in the approved work plan (AEEC, 2010) are relevant.

- Residential exposure to contaminated groundwater does not occur and is unlikely to occur in the future, as there are no existing residential areas or special subpopulations (such as infants or the elderly) present. Future land use at the subject property is anticipated to remain consistent with its zoning of light industrial.

- The level of risk present at the site is less than 1×10^{4} but equal to 1×10^{6} for carcinogens across all complete pathways and applicable COCs. The HI for individual substances and the THI across all complete pathways and applicable COCs is less than one.

- Exposure to ecological receptors through inhalation of volatilized COCs is considered to be a negligible, because volatiles disperse rapidly in outdoor air and airborne dust from surface soil does not contain detectable levels of COCs. Any exposure route that includes soil as a source medium is considered to be incomplete. There are currently no exposure routes by which an aquatic receptor species could come into contact with a COC. Therefore, the potential for adverse effects to receptor ecosystems and species is negligible.

7.2 RECOMMENDATIONS

In accordance with criteria identified in R315-101-1(b)(4), the following appropriate management activities are recommended for the Site:

- It is recommended that the extraction and/or use of groundwater at the Site be prohibited except for characterization purposes. All characterization activities must be conducted per Title R315 of the Utah Administrative Code.

8.0 REFERENCES

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TABLES

Table 1: Groundwater sample results from well installation and piezometers.

Well #	Date	MTBE	Benzene	Toluene	Ethylbenzene	Xylenes	Naphthalene	TPH (GRO)	TPH (DRO)	1,1-Dichloroetnane	cis-1,2-Dichloroethene	Vinyl chloride	Oil & Grease (mg/L)
MW1	03/04/05	< 2.0	< 1.0	< 2.0	< 2.0	< 2.0	< 2.0	< 20	< 20	nr	nr	nr	5.1
	10/15/09	nr	<2	<2	<2	<2	<2	<20	nr	nr	<2	<1	nr
MW2	03/04/05	< 2.0	< 1.0	< 2.0	< 2.0	< 2.0	< 2.0	< 20	< 20	nr	nr	nr	4.2
	10/15/09	nr	<2	<2	<2	<2	<2	<20	nr	nr	<2	<1	nr
MW3	03/04/05	< 2.0	< 1.0	< 2.0	< 2.0	< 2.0	< 2.0	< 20	< 20	nr	nr	nr	< 3.0
	10/15/09	nr	<2	<2	<2	<2	<2	<20	nr	nr	<2	<1	nr
MW7	03/04/05	14	< 1.0	< 2.0	< 2.0	< 2.0	< 2.0	< 20	< 20	nr	nr	nr	3.7
MW8	03/04/05	11	1	< 2.0	< 2.0	< 2.0	< 2.0	< 20	< 20	nr	nr	nr	5.3
	10/15/09	nr	<2	<2	<2	<2	<2	<20	nr	nr	<2	<1	nr
MW9	03/04/05	27	23	< 2.0	2	< 2.0	< 2.0	63	< 20	nr	10	7.3	3.8
	10/15/09	nr	7	< 2.0	< 2.0	< 2.0	< 2.0	30	nr	nr	<2	1.9	nr
	06/01/10	nr	nr	nr	nr	nr	nr	nr	nr	nr	<2	2.1	nr
	**6/1/2010	4.9	13.5	<1.0	0.8 J	<1.0	<1.0	<1.0	<1.0	0.5 J	1.5	3.0	nr
MW10	03/04/05	< 2.0	220	4000	560	4300	120	11000	110	nr	2.1	nr	5.1
	10/15/09	nr	<2	<2	<2	<2	<2	<20	nr	nr	<2	<1	nr
MW11	06/01/10	nr	nr	nr	nr	nr	nr	nr	nr	nr	<2	<1	nr
	**6/1/2010	6.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	nr
MW12	06/01/10	nr	nr	nr	nr	nr	nr	nr	nr	nr	<2	<1	nr
	**6/1/2010	4.6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.6 J	nr
B4 open boring	03/02/05	< 40	32	< 40	< 40	< 40	< 40	480	480	nr	nr	nr	nr
B4 cased	03/04/05	14	13	10	< 2.0	< 2.0	< 2.0	60	27	nr	17	nr	71
B7	03/04/05	150	20	12	4.4	9.1	< 2.0	140	38	nr	6.8	4.5	4.9
RBCA-I guideline		200	300	3000	4000	10000	700	10000	10000		n/a	n/a	10
ISL or MCL*		200	5	1000	700	10000	700	1000	1000		*70	*2	10

NOTES

The full range of chlorinated organics is not shown, only those parameters for which a detectable concentration was reported.
nr = not reported
Samples analyzed by American West Analytical Laboratories
Samples collected by Ellis Environmental except as otherwise indicated
Units ug/L except as otherwise indicated
* MCL is Maximum Contaminant Level for Drinking Water in Utah
** Split-sample collected by UDEQ - DSHW

Table 2
Dermal Exposure to Groundwater:
Input Values and Risk Characterization for Individual Substances

ABSORBED DOSE INPUT PARAMETERS	BENZENE	VINYL CHLORIDE	ETHYLBENZENE	CIS-1,2-DICHLOROETHYLENE	1,1-DICHLOROETHANE
C_{GW} (mg/L)	0.0135	0.003	0.0008	0.0015	0.0005
A_s (cm^2)	3300	3300	3300	3300	3300
RD (cm/hour)	8.4E-04	8.4E-04	8.4E-04	8.4E-04	8.4E-04
ET (hours/day)	8	8	8	8	8
EF (days/year)	250	250	250	250	250
ED (years)	1	1	1	1	1
K_v (1/1000 L / cm^3)	0.001	0.001	0.001	0.001	0.001
W_B (kg)	70	70	70	70	70
$AT_{Carcinogen}$ (days)	25,550	25,550	25,550	25,550	25,550
$AT_{Non\ carcinogen}$ (days)	365	365	365	365	365

CARCINOGENIC RISK CALCULATION					
LADD (mg/kg-day)	4.2E-08	9.3E-09	n/a	n/a	1.5E-09
Absorption Efficiency	20%	20%	n/a	n/a	20%
SF_{adm}	5.5E-02	7.2E-01	n/a	n/a	5.7E-03
SF_{abs}	2.8E-01	3.6E+00	n/a	n/a	2.9E-02
Cancer Risk	**1E-08**	**3E-08**	**n/a**	**n/a**	**4E-11**

NON-CARCINOGENIC RISK CALCULATION					
ADD (mg/kg-day)	2.9E-06	6.5E-07	1.7E-07	3.3E-07	1.1E-07
Absorption Efficiency	20%	20%	20%	20%	20%
RfD_{adm}	4.0E-03	3.0E-03	1.0E-01	1.0E-02	1.0E-01
RfD_{abs}	8.0E-04	6.0E-04	2.0E-02	2.0E-03	2.0E-02
Hazard Quotient	**4E-03**	**1E-03**	**9E-06**	**2E-04**	**5E-06**

Definitions:

ADD (mg/kg-day) = average daily dose
A_s (cm^2) = skin surface area available for contact
$AT_{Carcinogen}$ (days) = averaging time (carcinogen)
$AT_{Non\text{-}carcinogen}$ (days) = averaging time (non carcinogen)
C_{GW} (mg/L) = exposure point concentration
ED (years) = exposure duration
EF (days/year) = exposure frequency
ET (hours/day) = exposure time
K_v (1/1000 L / cm^3) = volumetric conversion factor
LADD (mg/kg-day) = lifetime average daily dose
RD (cm/hour) = dermal permeability constant
RfD_{abs} = reference dose (absorbed)
RfD_{adm} = reference dose (administered)
SF_{abs} = slope factor (absorbed)
SF_{adm} = slope factor (administered)
W_B (kg) = body weight

Table 3
Incidental Ingestion of Groundwater:
Input Values and Risk Characterization of Individual Substances

ADMINISTERED DOSE INPUT PARAMETERS	BENZENE	VINYL CHLORIDE	ETHYLBENZENE	CIS-1,2-DICHLOROETHYLENE	1,1-DICHLOROETHANE
C_{GW} (mg/L)	0.0135	0.003	0.0008	0.0015	0.0005
RC (L/hour)	0.05	0.05	0.05	0.05	0.05
ET (hours/day)	8	8	8	8	8
EF (days/year)	250	250	250	250	250
ED (years)	1	1	1	1	1
W_B (kg)	70	70	70	70	70
$AT_{Carcinogen}$ (days)	25,550	25,550	25,550	25,550	25,550
$AT_{Non-carcinogen}$ (days)	365	365	365	365	365

CARCINOGENIC RISK CALCULATION					
LADD (mg/kg-day)	7.5E-07	1.7E-07	n/a	n/a	2.8E-08
SE_{adm}	5.5E-02	7.2E-01	n/a	n/a	5.7E-03
Cancer Risk	***4E-08***	***1E-07***	**n/a**	**n/a**	**2E-10**

NON-CARCINOGENIC RISK CALCULATION					
ADD (mg/kg-day)	5.3E-05	1.2E-05	3.1E-06	5.9E-06	2.0E-06
RfD_{adm}	4.0E-03	3.0E-03	1.0E-01	1.0E-02	1.0E-01
Hazard Quotient	1E-02	4E-03	3E-05	6E-04	2E-05

Definitions:

ADD (mg/kg-day) = average daily dose

$AT_{Carcinogen}$ (days) = averaging time (carcinogen)

$AT_{Non carcinogen}$ (days) = averaging time (non-carcinogen)

C_{GW} (mg/L) = exposure point concentration

ED (years) = exposure duration

EF (days/year) = exposure frequency

ET (hours/day) = exposure time

LADD (mg/kg-day) = lifetime average daily dose

RC (L/hour) = contact rate

RfD_{adm} = reference dose (administered)

SF_{adm} = slope factor (administered)

W_B (kg) = body weight

Table 4
Johnson and Ettinger Model Results:
Risk Characterization of Individual Substances

CHEMICAL	Incremental Cancer Risk From Vapor Intrusion (unitless)	Hazard Quotient From Vapor Intrusion (unitless)
BENZENE	4.9E-07	4.9E-03
VINYL CHLORIDE	7.4E-07	2.0E-03
ETHYLBENZENE	n/a	8.7E-06
CIS-1,2-DICHLOROETHYLENE	n/a	3.4E-04
1,1-DICHLOROETHANE	3.5E-09	1.0E-05

Table 5
Total Exposure Cancer Risk and Hazard Index
(Simulataneous Exposure Across Multiple Pathways and COCs)

INCREMENTAL CANCER RISK	DERMAL EXPOSURE	INCIDENTAL INGESTION	VAPOR INTRUSION
Benzene	1.2E-08	4.2E-08	4.9E-07
Vinyl Chloride	3.3E-08	1.2E-07	7.4E-07
Ethylbenzene	n/a	n/a	n/a
Cis-1,2-Dichloroethylene	n/a	n/a	n/a
1,1-Dichloroethane	4.4E-11	1.6E-10	3.5E-09
Risk $_T$	5E-08	*2E-07*	*1*E-06
Total Exposure Cancer Risk	**1E-06**		

HAZARD INDEX			
Benzene	3.7E-03	1.3E-02	4.9E-03
Vinyl Chloride	1.1E-03	3.9E-03	2.0E-03
Ethylbenzene	8.7E-06	3 1E-05	8.7E-06
Cis-1,2-Dichloroethylene	1.6E-04	5.9E-04	3.4E-04
1,1-Dichloroethane	5.4E-06	2.0E-05	1.0E-05
HI	5E-03	***2E-02***	*7*E-03
Total Hazard Index	**3E-02**		

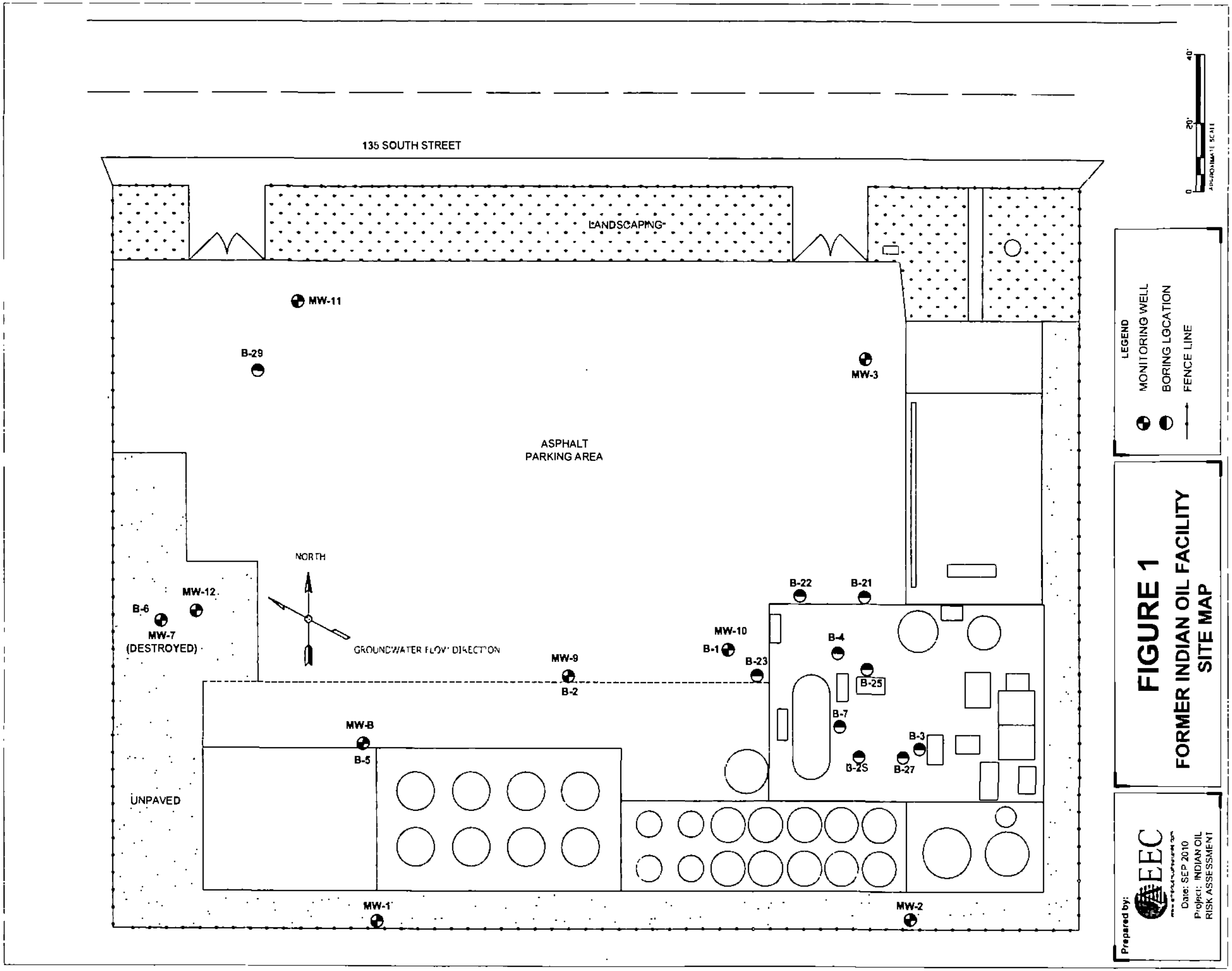
Definitions

$Risk_T$ = total oathway cancer nsk (unitless probability)

HI = hazard index (unitless)

COC = chemical of concern

FIGURES


135 SOUTH STREET
LANDSCAPING
MW-11
B-29
MW-3
ASPHALT
PARKING AREA
NORTH
GROUNDWATER FLOW DIRECTION
B-6
MW-12
MW-7
(DESTROYED)
MW-9
B-2
MW-10
B-1
B-23
B-22
B-21
B-4
B-25
B-7
B-3
B-26
B-27
MW-8
B-5
UNPAVED
MW-1
MW-2
0
20'
40'
APPROXIMATE SCALE
LEGEND
MONITORING WELL
BORING LOCATION
FENCE LINE
FIGURE 1
FORMER INDIAN OIL FACILITY
SITE MAP
Prepared by:
EEC
Date: SEP 2010
Project: INDIAN OIL
RISK ASSESSMENT

ıre 2. Conceptual Site Model

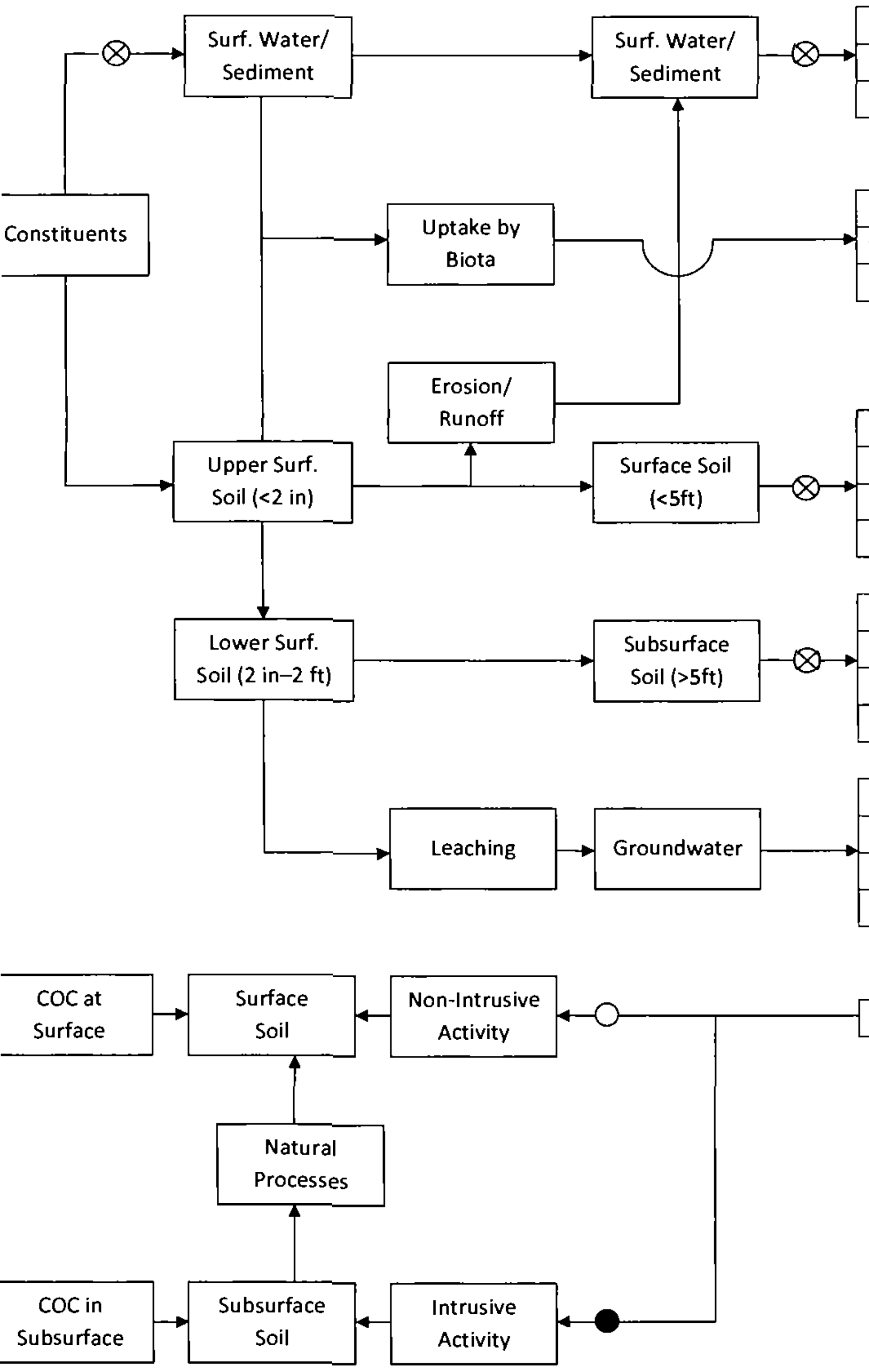
Indian Oil, Lindon UT

pleted By: ***Bryan Wheeler, AEEC*** ***Date Completed:*** ***30 AUG 2010***

SOURCE		INTERACTION			RECEPTORS
ꞮIMARY OURCE	SOURCE MEDIA	RELEASE MECHANISM	EXPOSURE MEDIA	EXPOSURE ROUTES	HUMAN & ECOLOGICAL RECEPTORS

Notes:

- No surface water present.
- No direct release.
- Approximate depth-to-groundwater is 3 to 4 ft.
- Soil type described as Payson silty clay loam, 0 to 1 percent slope.



	CURRENT/FUTURE				
	Residents	Construction Workers	Installation Workers	Site Visitors	Ecological Receptors
Ingestion as DW	--	○	○	○	--
Incidental Ingestion	--	○	○	○	--
Dermal Contact	--	○	○	○	--
Ingestion of:					
Livestock/Crops	--	n/a	n/a	n/a	--
Game/Fish	--	n/a	n/a	n/a	--
Other Biota	--	○	○	○	--
Incidental Ingestion	--	○	○	○	--
Dermal Contact	--	○	○	○	--
Inhalation (dust)	--	○	○	○	--
Inhalation (volatiles)	--	○	○	○	--
Incidental Ingestion	--	○	○	○	--
Dermal Contact	--	○	○	○	--
Inhalation (dust)	--	○	○	○	--
Inhalation (volatiles)	--	○	○	○	--
Ingestion as DW	--	○	○	○	--
Incidental Ingestion	--	●	●	●	--
Inhalation (volatiles)	--	●	●	●	--
Dermal Contact	--	●	●	●	--
Access to Site	--	▲	▲	▲	--

LEGEND

- ● Potential Complete Pathway
- ○ Incomplete Pathway
- -- Receptor Not Present
- n/a Not Applicable
- ▲ Potential Receptor
- ⊗ Pathway Not Present

APPENDIX A

DATA ENTRY SHEET

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No (numbers only, no dashes)	ENTER Initial groundwater conc. C_W (µg/L)	Chemical
71432	1.35E+01	Benzene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	122	CL	13	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm²)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm³)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm³/cm³)
CL			CL	1.48	0.442	0.168

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3$)$^{-1}$	Reference conc., RfC (mg/m^3)
8.80E-02	9.80E-06	5.54E-03	25	7,342	353.24	562.16	5.89E+01	1.79E+03	7.8E-06	3.0E-02

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
107	0.274	0.245	1.27E-09	0.865	1.10E-09	46.88	0.442	0.067	0.375	4.000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	8.091	3.12E-03	1.33E-01	1.76E-04	6.05E-03	6.96E-05	1.57E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
107	15	1.60E+03	0.10	8.33E+01	6.05E-03	4.00E+02	4.64E+149	8.49E-05	1.52E-01	7.8E-06	3.0E-02

RESULTS SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.79E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
4.9E-07	4.9E-03

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc. C_W (µg/L)	Chemical
75343	5.00E-01	1,1-Dichloroethane

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	122	CL	13	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
CL			CL	1.48	0.442	0.168

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc, RfC (mg/m^3)
7.42E-02	1.05E-05	5.61E-03	25	6,895	330.55	523.00	3.16E+01	5.06E+03	1.6E-06	5.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
107	0.274	0.245	1.27E-09	0.865	1.10E-09	46.88	0.442	0.067	0.375	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	7,417	3.32E-03	1.41E-01	1.76E-04	5.10E-03	6.11E-05	1.37E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m^3)	Unit risk factor, URF (μg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
107	15	7.06E+01	0.10	8.33E+01	5.10E-03	4.00E+02	3.13E+177	7.46E-05	5.27E-03	1.6E-06	5.0E-01

RESULTS SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (μg/L)	Indoor exposure groundwater conc., noncarcinogen (μg/L)	Risk-based Indoor exposure groundwater conc., (μg/L)	Pure component water solubility, S (μg/L)	Final indoor exposure groundwater conc., (μg/L)
NA	NA	NA	5.06E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to Indoor air, noncarcinogen (unitless)
3.5E-09	I.0E-05

MESSAGE SUMMARY BELOW:

END

]

DATA ENTRY SHEET

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc. C_W (μg/L)	Chemical
156592	1.50E+00	cis-1,2-Dichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature T_S (°C)	ENTER Average vapor flow rate into bldg (Leave blank to calculate) Q_{soil} (L/m)
15	122	CL	13	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm²)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm³)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm³/cm³)
CL			CL	1.48	0.442	0.168

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration

CHEMICAL PROPERTIES SHEET

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^3/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
7.36E-02	1.13E-05	4.07E-03	25	7,192	333.65	544.00	3.55E+01	3.50E+03	0.0E+00	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
107	0.274	0.245	1.27E-09	0.865	1.10E-09	46.88	0.442	0.067	0.375	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	7,704	2.36E-03	1.00E-01	1.76E-04	5.06E-03	6.82E-05	1.53E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
107	15	1.51E+02	0.10	8.33E+01	5.06E-03	4.00E+02	8.41E+178	8.29E-05	1.25E-02	NA	3.5E-02

RESULTS SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	3.50E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	3.4E-04

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

END

]

DATA ENTRY SHEET

GW-SCREEN
version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc below)

YES [x]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc. C_W (µg/L)	Chemical
100414	8.00E-01	Ethylbenzene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg (Leave blank to calculate) Q_{soil} (L/m)
15	122	CL	13	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
CL			CL	1.46	0 442	0.168

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens AT_{NC} (yrs)	ENTER Exposure duration ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
7.50E-02	7.80E-06	7.86E-03	25	8,501	409.34	617.20	3.63E+02	1.69E+02	0.0E+00	1.0E+00

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm³/cm³)	Vadose zone effective total fluid saturation, S_{te} (cm³/cm³)	Vadose zone soil intrinsic permeability, k_i (cm²)	Vadose zone soil relative air permeability, k_{rg} (cm²)	Vadose zone soil effective vapor permeability, k_v (cm²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm³/cm³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm³/cm³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm³/cm³)	Floor-wall seam perimeter, X_{crack} (cm)
107	0.274	0.245	1.27E-09	0,865	1.10E-09	46.88	0,442	0,067	0,375	4,000

Bldg. ventilation rate, $Q_{building}$ (cm³/s)	Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm²/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)
1.69E+04	1.00E+06	4.00E-04	15	10,121	3.84E-03	1.64E-01	1.76E-04	5.15E-03	5.64E-05	1,27E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} (ug/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m³)	Unit risk factor, URF $(ug/m^3)^{-1}$	Reference conc., RfC (mg/m³)
107	15	1.31E+02	0.10	8.33E+01	5,15E-03	4,00E+02	4.13E+175	6.90E-05	9,03E-03	NA	1,0E+00

RESULTS SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (μg/L)	Indoor exposure groundwater conc., noncarcinogen (μg/L)	Risk-based indoor exposure groundwater conc., (μg/L)	Pure component water solubility, S (μg/L)	Final indoor exposure groundwater conc., (μg/L)
NA	NA	NA	1.69E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	8.7E-06

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
75014	3 00E+00	Vinyl chloride (chloroethene)

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	122	CL	13	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
CL			CL	1 48	0 ·M2	0.168

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
1.06E-01	1.23E-05	2.69E-02	25	5,250	259.25	432.00	1.86E+01	8.80E+03	8.8E-06	1.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm³/cm³)	Vadose zone effective total fluid saturation, S_{te} (cm³/cm³)	Vadose zone soil intrinsic permeability, k_i (cm²)	Vadose zone soil relative air permeability, k_{rg} (cm²)	Vadose zone soil effective vapor permeability, k_v (cm³)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm³/cm³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm³/cm³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm³/cm³)	Floor-wall seam perimeter, X_{crack} (cm)
107	0.274	0.245	1.27E-09	0.865	1.10E-09	46.88	0.442	0.067	0.375	4,000

Bldg. ventilation rate, $Q_{building}$ (cm³/s)	Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm²/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)
1.69E+04	1.00E+06	4.00E-04	15	4,966	1.89E-02	8.07E-01	1.76E-04	7.28E-03	6.95E-05	1.57E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m³)	Unit risk factor, URF (μg/m³)$^{-1}$	Reference conc., RfC (mg/m³)
107	15	2.42E+03	0.10	8.33E+01	7.28E-03	4.00E+02	1.85E+124	8.49E-05	2.06E-01	8.8E-06	1.0E-01

RESULTS SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	8.80E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
7.4E-07	2.0E-03

MESSAGE SUMMARY BELOW:

END

APPENDIX B

State of Utah
DEPARTMENT OF NATURAL RESOURCES

MICHAEL R. STYLER
Executive Director

Division of Wildlife Resources

JAMES F. KARPOWITZ
Division Director

JON M. HUNTSMAN, JR.
Governor

GARY R. HERBERT
Lieutenant Governor

July 12, 2010

Bryan Wheeler
AEEC, LLC
3489 West, 2100 South, Suite 150
Salt Lake City, Utah 84119

Subject: Species of Concern Near Terracon Project No. 6107703

Dear Bryan Wheeler:

I am writing in response to your email dated July 6, 2010 regarding information on species of special concern proximal to the proposed Indian Oil Facility located al 1155 West 135 South in Lindon, Utah (Section 32 of Township 5 South, Range 2 East, SLB&M).

The Utah Division of Wildlife Resources (UDWR) does not have records of occurrence for any threatened, endangered, or sensitive species within the project area noted above. However, in the vicinity there are recent records of occurrence for June sucker, a species included on the *Utah Sensitive Species List*.

The information provided in this letter is based on data existing in the Utah Division of Wildlife Resources' central database at the time of the request. It should not be regarded as a final statement on the occurrence of any species on or near the designated site, nor should it be considered a substitute for on-the-ground biological surveys. Moreover, because the Utah Division of Wildlife Resources' central database is continually updated, and because data requests are evaluated for the specific type of proposed action, any given response is only appropriate for its respective request.

In addition to the information you requested, other significant wildlife values might also be present on the designated site. Please contact UDWR's habitat manager for the central region, Mark Farmer, at (801) 491-5653 if you have any questions.

Please contact our office at (801) 538-4759 if you require further assistance.

Sincerely,

Sarah Lindsey

Sarah Lindsey
Information Manager
Utah Natural Heritage Program

cc: Mark Farmer, CRO